Table-1. Variable Definitions. Descriptive Statistics, and Data Sources

ELL	Reimbursement by NECA plus matching state funds paid to LECs per household for the subscriber line charge waiver.	0.628	1.287	Federal-State Joint Board. Monitoring Report (1994)
ELU	Reimbursement by NECA to LEC's per household for connection assistance.	0.043	0.092	Federal-State Joint Board. Monitoring Report (1994)
ELLU	ELL + ELU	0.671	1.327	Federal-State Joint Board, Monitoring Report (1994)
EUSF	The Universal Service Fund per household.	3.48	4.80	Federal-State Joint Board. Monitoring Report
Y	Disposable personal income per capita.	13181.55	2114.58	Regional Economic Information System, Bureau of Economic Analysis
RL	Percent of state's population residing in rural areas in 1990.	32.24	14.53	U.S. Bureau of the Census. 1990 Census of Population
BL	Percent of state's population which was black in 1990.	9.82	9.28	U.S. Bureau of the Census. 1990 Census of Population
HP	Percent of state's population which was of Hispanic origin in 1990.	5.25	7.55	U.S. Bureau of the Census. 1990 Census of Population

Table-2. Correlation Matrix of the Variables

	PR	IR	WFR	LD1	ELLU	EUSF	Y	RL	BL	HP
PR	1.000	-0.426	-0.370	-0.210	0.201	-0.253	0.630	-0.317	-0.439	-0.163
IR	-0.426	1.000	0.143	0.513	-0.317	-0.259	-0.083	-0.067	0.395	0.161
WFR	-0.370	0.143	1.000	0.224	-0.094	-0.061	-0.331	0.451	0.162	-0.242
LD1	-0.210	0.513	0.224	1.000	-0.351	-0.447	-0.183	0.000	0.000	0.000
ELLU	0.201	-0.317	-0.094	-0.351	1.000	0.198	0.115	0.057	-0.245	0.132
EUSF	-0.253	-0.259	-0.061	-0.447	0.198	1.000	-0.352	0.355	-0.084	0.089
Y	0.630	-0.083	-0.331	-0.183	0.115	-0.352	1.000	-0.574	-0.043	0.147
RL	-0.317	-0.067	0.451	0.000	0.057	0.355	-0.574	1.000	-0.013	-0.534
BL	-0.439	0.395	0.162	0.000	-0.245	-0.084	-0.043	-0.013	1.000	-0.148
HP	-0.163	0.161	-0.242	0.000	0.132	0.089	0.147	-0.534	-0.148	1.000

V. Estimation Methodology and Results

The demand model underlying the empirical specification stems from a discrete choice model of household behavior, wherein households choose to either subscribe or not subscribe to the public switched network. Given the aggregated nature of the dependent variable, we eschew the logit/probit estimation procedures and instead utilize a linear probability model. This specification of the dependent variable, however, raises two econometric issues. First, ϵ will be heteroskedastic. Second, the pooled nature of the data gives rise to the potential for ϵ to be autocorrelated over time and heteroskedastic across states.

To account for these considerations, a two-stage estimation procedure is utilized. First, to account for the known heteroskedasticity, the ***minimum chi-square method*** (a weighted least-squares technique) is used.[14] The weights for this procedure, w_{it}, are

$$(6) \qquad w_{it} = \left(\frac{n_{it}}{\hat{p}_{it}(1-\hat{p}_{it})} \right)^{\frac{1}{2}},$$

where $\hat{p}_{it}$ is the predicted value of the dependent variable, and n_{it} is the number of households. Let e_{it} be the weighted disturbance term from equation (6), i.e. $e_{it} = w_{it} \cdot \epsilon_{it}$. The following error structure is then assumed:

$$(7) \qquad E(e_{it}, e_{js}) = \begin{cases} 0 & i \neq j \ \forall \ s, t \\ \dfrac{\sigma_{ui}^2}{1-\rho_i^2} & i = j, \ s = t \\ \dfrac{\sigma_{ui}^2}{1-\rho_i^2}\rho_i^{t-s} & i = j, \ t > s \end{cases}.$$

Thus, e_{it} is assumed to be heteroskedastic, cross-sectionally independent, and autoregressive to the first order within each state. Accordingly, e_{it} can be written as,

$$(8) \qquad e_{it} = \rho_i e_{it-1} + u_{it},$$

where u_{it} obeys the properties:

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[14] See Maddala (1983).

model of household behavior, wherein households choose to either subscribe or not subscribe to the public switched network. Given the aggregated nature of the dependent variable, we eschew the logit/probit estimation procedures and instead utilize a linear probability model. This specification of the dependent variable, however, raises two econometric issues. First, ϵ will be heteroskedastic. Second, the pooled nature of the data gives rise to the potential for ϵ to be autocorrelated over time and heteroskedastic across states.

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where $\hat{p}_{it}$ is the predicted value of the dependent variable, and n_{it} is the number of households. Let e_{it} be the weighted disturbance term from equation (6), i.e. $e_{it} = w_{it} \cdot \epsilon_{it}$. The following error structure is then assumed:

$$(7) \qquad E(e_{is}, e_{jt}) = \begin{cases} 0 & i \neq j \ \forall \ s, t \\ \dfrac{\sigma_{ui}^2}{1 - \rho_i^2} & i = j, \ s = t \\ \dfrac{\sigma_{ui}^2}{1 - \rho_i^2} \rho_i^{t-s} & i = j, \ t > s \end{cases}.$$

Thus, e_{it} is assumed to be heteroskedastic, cross-sectionally independent, and autoregressive to the first order within each state. Accordingly, e_{it} can be written as,

$$(8) \qquad e_{it} = \rho_i e_{it-1} + u_{it},$$

where u_{it} obeys the properties:

---

[14]See Maddala (1983).

$$(9) \qquad E(u_{it}, u_{js}) = \begin{cases} 0 & i \neq j \ \forall \ s, t \\ \sigma_{ui}^2 & i = j, \ s = t \end{cases} .$$

The second stage of our estimation procedure utilizes Kmenta's (1986) technique to obtain generalized least squares (GLS) estimators for pooled data. First, consistent estimates of the ρ_i's are obtained by the sample coefficient of correlation between $\hat{e}_{it}$ and $\hat{e}_{it-1}$ which are the current and lagged residuals obtained from the weighted least squares regression. Next the Prais-Winsten (P-W) transformation is applied to the data weighted by w_{it}. Consistent estimates of σ_{ui}^2 can then be found using the residuals, $\hat{u}_{it}$, obtained from the regression of the weighted P-W transformed equation. Finally the weighted P-W equation is divided through by $\hat{\sigma}_{ui}$ and reestimated to obtain our GLS estimators.

Table-3. Estimation Results

	Coefficient	Std. Error	t-Statistic	Elasticity[1]
Intrcpt	0.93748	0.007933	118.1681	-----------
IR	-0.00036	0.000086	-4.2053	-0.01053
WFR	-0.00155	0.000315	-4.90477	-0.01901
LD1[2]	-0.04951	0.017074	-2.89982	-0.00575
ELLU	0.000759	0.000387	1.960678	0.001098
EUSF	-0.00018	0.000147	-1.25211	-0.00144
Y	5.23E-06	3.62E-07	14.45956	0.075812
RL	-0.00048	0.000066	-7.28238	-----------
BL	-0.0014	0.000083	-16.9914	-----------
HP	-0.00186	0.000145	-12.8338	-----------

$R^2 = 0.7203$

[1]Elasticities were calculated using 1993 average prices, expenditures, and penetration levels.
[2]Equation (5) was also estimated using LD2 without displaying any significant differences in the regression results.

Estimation results are reported in Table 3. Beginning with the three price variables (IR, WFR, and LD1), we find that the coefficient estimates are highly significant and negative in sign as expected. Thus, the installation charge, the monthly recurring charge, and long-distance rates are all seen to influence household penetration rates. Additionally, the implied price elasticities (also reported in table 3) are consistent with earlier telecommunications studies.[15] An important finding stems from the estimated coefficient on the long-distance price variable (LD1). Specifically, we find that long-distance prices are statistically significant and inversely related to household penetration rates. This result is also consistent with Hausman, Tardiff, and Belinfante (1993) who, utilizing an aggregate index of long-distance prices, also find that such prices significantly influence the degree of universal service.

We also find that household demographic characteristics are a major factor in the decision to purchase access to the telecommunications network. While the level of aggregation of our own study limits the range of possible variables, such as education or age, which vary only slightly across states, we find that other demographic variables such as race and per capita income are strong predictors of the level of residential telephone subscription within a state. Consistent with prior studies of telecommunications demand, both BL and HP are negative and significant. The negative and significant sign of RL supports the hypothesis that households in rural areas generally have smaller calling circles and, thus, a lower demand for telecommunications services. Finally, we find that household income is both positive and highly

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[15] Perl (1983) finds that the elasticity of the installation rate is -0.0034 while the elasticity of the flat rate is -0.0175 for areas with a measured service option and -0.0492 for areas where only flat rate service is offered. However, Perl's study does not include a measure of long-distance prices. More recently, Hausman, Tardiff, and Belinfante (1993) report an elasticity for installation charges of -0.02 and an elasticity for basic access to measured rate service of -0.0052.

significant. Moreover, our calculated elasticity is in the same range as other reported income elasticities, including Perl's (1983) estimate of 0.1296 and Taylor and Kridel's (1990) estimate of 0.042.

Finally, consider the impact on universal service caused by the targeted (Lifeline and Link-Up) and untargeted (High Cost Assistance) programs. First, the coefficient on the variable representing targeted subsidy expenditures (ELLU) is positive and statistically significant. Thus, *ceteris paribus*, the expenditure on targeted subsidy mechanisms aimed at households judged to be at risk of dropping off the telephone network are found to accomplish their intended purpose of promoting household penetration rates. An important caveat to this conclusion stems from the fact that, under the current method for raising the funds used for targeted household assistance, long-distance costs (and, therefore, prices) are increased. And, as we have already noted, increases in long-distance rates negatively affect household penetration. Therefore, the *net* effect of even the targeted subsidy programs is in doubt.

Second, the coefficient on the untargeted subsidy expenditures (EUSF) is negative though statistically insignificant.[16] That is, we cannot reject the null hypothesis that the untargeted USF subsidy scheme has had no impact whatsoever on household penetration rates in the post-divestiture period. Moreover, the USF program is currently funded by a method which increases long-distance rates. This indicates that the current untargeted subsidy flows, including the impact of financing those flows, actually reduce household subscription levels. Indeed, this

[16]In order to examine the robustness of this and other primary results, several alternative model specifications were attempted. These included logarithmic transformations of the variables and inclusion of interaction variables. None of these alternative specifications were found to significantly affect our primary conclusions.

negative impact of the financing mechanism on household penetration rates is considerably more severe in the case of the untargeted High Cost Assistance program, because the total subsidy flow involved in the untargeted program is roughly 2.5 times higher than that for the targeted Lifeline and Link-Up programs. Thus, our findings strongly suggest that the untargeted subsidy program is not only expensive, but it actually works against achievement of the policy objective of universal service. Accordingly, penetration rates would go up if this program were abolished.

VI. Conclusion

Public policy programs designed to promote social goals through cross-subsidization are not at all uncommon. In fact, in regulated industries, they are virtually ubiquitous. While economists have argued for some time that both the subsidy design and the financing of any such subsidy may influence the efficacy of such programs, relatively little comparative evidence on this subject has heretofore been brought to light.

The growing concern over the provision and maintenance of universal service in the post-divestiture period has given rise to large-scale subsidy mechanisms that are both targeted (Lifeline and Link-Up) and untargeted (High Cost Assistance). The financing of both of these subsidy schemes presently occurs through charges (taxes) placed upon long-distance customers. The advent of these side by side programs permits us to examine their effectiveness in accomplishing the intended effect--the promotion of universal service. Based upon a demand model of household subscription decisions, we have developed an empirical model of household penetration rates for telephone service in the 48 contiguous states for the 1985-1993 period.

The estimation results provide considerable insight into the economic determinants of household subscription decisions. Additionally, the results generate important evidence regarding the efficacy of alternative subsidy mechanisms. As anticipated by economic logic and favored by oral economic tradition, targeted subsidy programs are found to be much more effective than untargeted programs. Indeed, at least in the case of the telecommunications industry, our estimation results fail to detect any contribution whatsoever of the untargeted USF expenditures on universal service. In contrast, targeted subsidy expenditures are found, *ceteris paribus*, to promote increases in household penetration rates.

Also, given the negative and significant coefficient on long-distance prices revealed in the estimations, the results clearly indicate that the financing mechanism used to promote these subsidy programs has been counter-productive to the achievement of the intended goal. This finding underscores the importance of the financing mechanism used to support such subsidy programs. It is quite possible (and appears to be the case here) that the funding system used can frustrate achievement of the very objective being pursued, whether that objective is pursued through a targeted or untargeted subsidy scheme.

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VI. Publications

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"The 'Rush to Transplant' and Organ Shortages" (with Andy H. Barnett), Economic Inquiry, forthcoming.

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Reviewed Antitrust Economics: Merger, Contracting and Strategic Behavior, Oliver E. Williamson (Oxford: Basil Blackwell, 1990) Managerial and Decision Economics, forthcoming.

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Reviewed New Developments in the Analysis of Market Structure, Joseph E. Stiglitz and G. Frank Mathewson, eds. (Cambridge, Mass.: The MIT Press, 1986) Antitrust Bulletin, Vol. 34 (Summer 1989), pp. 429-435.

Edited special memorial issue of the Survey of Business, Vol. 20 (Summer 1984) entitled "Industrial Organization and Antitrust Policy," in honor of Professor P. David Qualls.

Reviewed Economic Regulation: Essays in Honor of James R. Nelson, Kenneth D. Boyer and William G. Shepherd, eds. (East Lansing: MSU Public Utilities Paper, 1981) Southern Economic Journal, Vol. 49 (April 1983), pp. 1197-1198.

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"The Forward Exchange Rate: Its Determination and Behavior as a Predictor of the Future Spot Rate," American Statistical Association Proceedings of the Business and Economic Statistics Section, American Statistical Association, Washington, D.C., 1974.

VII. Papers in Progress

"Entry and Barriers to Entry: Toward an Operational Index" (with John W. Mayo).

"A Dynamic Model of Advertising by the Regulated Firm" (with John W. Mayo and Francois Melese).

"Open Entry and Local Telephone Rates: The Economics of IntraLATA Toll Competition" (with John W. Mayo, Larry R. Blank, and Simran Kahai)

"Is the 'Dominant Firm' Dominant? An Empirical Analysis of AT&T's Market Power" (with Simran K. Kahai and John W. Mayo).

"Dominant Firm Pricing with Competitive Entry and Regulation: The Case of IntraLATA Toll" (with Larry R. Blank and John W. Mayo)

"Scope, Learning, and Cross-Subsidy: Organ Transplants in a Multi-Division Hospital -- A Comment and Extension" (with Andy H. Barnett and T. Randolph Beard)

"Telecommunications Regulation and the PUCs: Guardrails or Speedbumps on the Information Highway?" (with John W. Mayo)

"Vertical Integration to Raise Rivals' Costs" (with T. Randolph Beard)

"A Note on the Symmetry of Vertical Price and Output Restraints: The Missing Link"

VIII. Testimony

Regulation of Interexchange Carriers, Docket No. 127, 140-U (Phase IV), Before the Corporation Commission of the State of Kansas, October, 1984.

United States of America Before Federal Trade Commission in the Matter of the B.F. Goodrich Company, Diamond Shamrock Chemicals Company, and Diamond Shamrock Plastics Corporation (Merger Case), January, 1985.

In the Matter of an Investigation of Intrastate Separations, Settlements and Intrastate Toll Rate of Return, Docket No. 83-042-U, Before the Arkansas Public Service Commission, April, 1985.

Petition of General Counsel for Initiation of an Evidentiary Proceeding to Establish Telecommunications Submarkets, Docket No. 6264, Before the Public Utility Commission of Texas, September, 1985.

In the Matter of Occidental Petroleum Corporation and Tenneco Plastics Corporation (Merger Case-Preliminary Injunction Hearing in Federal District Court, Washington, D.C.), March 1986.

Testified by affidavit in Federal Court in Columbus, Georgia, on behalf of Royal Crown Cola. Temporary restraining order hearing against the Coca-Cola/Dr. Pepper and the Pepsico/7-Up mergers.

In the Matter of the Petition of AT&T Communications of the Pacific Northwest, Inc. for Classification as a Competitive Telecommunications Company, Cause No. U-86-113, Before the Washington Utilities and Transportation Commission, November, 1986.

Testified before the Texas State Legislature (committees in both the House and the Senate) concerning appropriate regulatory policy in the post divestiture long-distance telecommunications industry, March, 1987.

Performed a complete damage study for the City of Chattanooga in a bid-rigging case in the sewer construction industry. Testified by deposition, July, 1986.

The Review of Private Line Services, Case No. 6633, Before the Public Utilities Commission of the State of Colorado, September, 1987.

In the Matter of Alternative Regulatory Frameworks for Local Exchange Carriers, Docket I.87-11-033, Before the Public Utilities Commission of the State of California, January 1988.

In the Matter of the Petition of the General Counsel for an Evidentiary Proceeding to Determine Market Dominance Among Interexchange Telecommunications Carriers, Docket No. 7790, Before the Public Utility Commission of Texas, June 1988.

In the Matter of the Investigation for the Purpose of Determining the Classification of the Services Provided by Interexchange Telecommunications Companies within the State of Missouri, Case No. TO-88-142, Before the Public Service Commission of the State of Missouri, February, 1989.

In Re: Investigation of the Revenue Requirements, Rate Structures, Charges, Services, Rate of Return and Construction Program of AT&T Communications of the South Central States, Inc. in its Louisiana Intrastate Operations, Appropriate Level of Access Charges and All Matters Relevant to the Rates and Services Rendered by the Company, Docket No. U-17970, Before the Louisiana Public Service Commission, June, 1989.

In the Matter of: An Inquiry into IntraLATA Toll Competition and Appropriate Compensation Scheme for Completion of IntraLATA Calls by Interexchange Carriers and WATS Jurisdictionality, Administrative Case No. 323, Phase I, Before the Public Service Commission, Commonwealth of Kentucky, February, 1990.

In the Matter of the Application of AT&T Communications of the Southwest, Inc., to Institute Flexible Price Cap Regulation of Its Intrastate Services, Docket No. 167, 493-U, 90-AT&T-19-R, Before the State Corporation Commission of the State of Kansas, February, 1990.

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Order of the Mississippi Public Service Commission Initiating Hearings Concerning (1) IntraLATA Competition in the Telecommunication Industry and (2) Payment of Compensation by Interexchange Telecommunication Carriers and Resellers to Local Exchange Companies in Addition to Access Charges, Docket No. 90-UA-0280, Before the Mississippi Public Service Commission, May, 1991.

Petition of AT&T of the South Central States, Inc. for Reduced Regulation of Intrastate Telecommunications Services. Case No. 92-297, Before the Public Service Commission, Commonwealth of Kentucky, January, 1993.

Tariff Filing by South Central Bell Telephone Company for Presumptively Valid Regulation for New Optional Services and for Rate Reductions in Existing Services (Tariff 93-039), Docket No. 93-03038, Before the Tennessee Public Service Commission, April, 1993.

In the Matter of Investigation to Consider Whether Competitive Intrastate Offerings of Long Distance Telephone Service Should be Allowed in North Carolina and What Rules and Regulations Should be Applicable to Such Competition if Authorized, Docket No. P-100, SUB 72, Before the North Carolina Utilities Commission, July, 1993.

Ex-Parte: In the Matter of Investigating Telephone Regulatory Methods Pursuant to Virginia Code, Section 56-235.5, et cetera, Case No. PUC930036, Before the Virginia State Corporation Commission, March, 1994.

City of Tuscaloosa, et al. vs. Harcros Chemicals, Inc., et al., Case No. CV-92-G-1614-S, Northern District of Alabama. Retained by three of the defendants in a bid-rigging case in the repackaged chlorine industry. Deposition taken in August, 1994.

Application of Contel of Virginia, Inc. d/b/a GTE Virginia to Implement Community Calling Plans in Various GTE Virginia Exchanges Within the Richmond and Lynchburg LATAs, Case No. PUC930035, Before the Virginia State Corporation Commission, October, 1994.

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Dissertation: "Diversification and Performance in the U.S. Energy Industry"

PREVIOUS POSITIONS:

Research Associate Professor, Center for Business and Economic Research, and Associate Professor of Economics, Department of Economics, The University of Tennessee, Knoxville, July 1989-June 1994.

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Chief Economist, Democratic Staff, U.S. Senate Small Business Committee, Washington, D.C., June 1984-June 1985.

Visiting Assistant Professor of Economics, Virginia Polytechnical Institute and State University, Blacksburg, Virginia, Fall 1982.

Dissertation Fellow, Center for the Study of American Business, Washington University, 1980-1981.

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Energy Research Fellow, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1979.

Research Assistant, Graduate School of Business Administration, Washington University, 1979-1980.

Research Assistant, Institute for Urban and Regional Studies, Washington University, 1978.

Instructor, University College, Washington University, 1978.

HONORS, AWARDS, AND GRANTS:

Undergraduate: Mosley Economics Prize (#1 graduating economics major), Alpha Chi (scholastic), Blue Key, Senior Honors Seminar.

Graduate: 1977-78 University Fellowship, Washington University; 1979 National Academy of Sciences Young Research Fellow, Laxenburg, Austria; 1979-81 President, Washington University Economics Graduate Student Association; 1980-81 Dissertation Fellowship, Center for the Study of American Business, Washington University.

Post-Graduate: 1983-1985 Summer Faculty Research Fellowships, College of Business Administration, The University of Tennessee; 1988 South Central Bell Research Grant; Research Affiliate, Center of Excellence for New Venture Analysis, The University of Tennessee.

FIELDS OF SPECIALIZATION:

Industrial Organization
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COURSES TAUGHT:

Undergraduate: Principles of Microeconomics, Current Economic Problems, Government and Business, Intermediate Microeconomics, Energy Economics

Graduate: Managerial Economics (MBA), Managing in a Regulated Economy (MBA), Economics (Executive MBA), Industrial Organization and Public Policy (Ph.D.), The Economics of Antitrust and Regulation (Ph.D.)

PUBLICATIONS:

A. JOURNAL ARTICLES

"Cross-Subsidies in Telecommunications: Roadblocks on the Road to More Intelligent Telephone Pricing" (with David L. Kaserman), Yale Journal on Regulation, Volume 11, Winter 1994, pp. 120-147.

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B. BOOKS, MONOGRAPHS, AND OTHER PUBLICATIONS

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